Influence of different production systems on body mass and number of earthworms

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Abstract

The present study examines how different production systems (i.e. control, organic, integrated, biodynamic and conventional) influence the body mass and number of earthworms in soil after harvesting cabbage, wheat and pumpkins. Experiments were conducted in October 2009 at the experiment fields of the Faculty of Agriculture and Life Sciences (FKBV) in Pivola. A mixture of 1/3 white mustard and 2/3 water, which is not harmful for earthworms, was used. Earthworms were divided by appearance into three groups (i.e. small, middle and large) and weighed (wet). The average population of earthworms was higher in the biodynamic (24.00) and organic (22.41) production systems than in the control, conventional and integrated systems. The average body mass of earthworms was the largest in the organic (22.25 g/0.25 m²) and biodynamic (18.83 g/0.25 m²) production systems. Earthworms reached the highest average body mass (1,440 kg/ha) after the growth of pumpkins.

Key words: earthworms, white mustard, production systems, body mass, number

Introduction

Earthworms are a major component of soil fauna communities in most ecosystems and comprise a large proportion of macrofauna biomass. Numerous investigators, reviewed recently by Bhadauria and Gopal Saxena (2010), have pointed out the beneficial effects of earthworms on soil properties. As earthworms pass through the soil they eat, decompose and deposit the castings. Their activity is beneficial because it can enhance soil nutrient cycling through the rapid incorporation of detritus into mineral soils. In addition to this mixing effect, mucus production associated with water excretion in earthworm guts also enhances the activity of other beneficial soil microorganisms. Earthworms accelerate the mineralization as well as the turnover of soil organic matter. The increased transfer of organic C and N into soil aggregates indicates the potential for earthworms to facilitate soil organic matter stabilization and accumulation in agricultural systems. In addition to the significant enhancement of nutrients concentration (N, P, K and Ca, which are easily assimilable by plants in fresh cast depositions), the earthworm activity positively influences soil structure, gas dynamics and water flow in the soil (VandenBygaart et al., 2000). The population of earthworms in an agricultural field is influenced by the intensity and number of soil disturbance events (i.e. tillage and traffic), the abundance and quality of food sources (i.e. organic manure, crop rotation and cover crops), the chemical environment of the soil (i.e. pH, salinity and agrochemical inputs) and the soil microclimate. Agrochemical inputs such as heavy metals and many commonly applied pesticides are shown to have detrimental effects on earthworm communities and their activity (Lee, 1985; Edvards and Bohlen, 1992; Greigh-Smith et al., 1992).

The aim of the present study was to evaluate the influence of the examined production systems on earthworm population and its body mass, and to determine how the earthworm population varies across different crops in crop rotation.
Materials and methods

The experiment was conducted in the frame of a long-term field trial at the University Agricultural Centre of the University of Maribor in Pivola near Hoče (46°28ʹN, 15°38ʹE, 282 m a.s.l), where four production systems (i.e. conventional (CON), integrated (INT), organic (ORG) and bio-dynamic (BD)) were arranged in a randomized complete block split-plot design with four replications (i.e. control plot, cabbage, wheat and pumpkins). The production systems differed mostly in plant protection and fertilization strategies and were defined by the valid legislation and standards, including a control plot (managed without fertilizers and plant protection application) and four production systems. Systems were managed in accordance with the following national and European rules and legislation: Good Agriculture Practice, Rules (MKGP, 2002; MKGP, 2004), Guidelines for integrated field crops (Džuban et al., 2009a) and vegetable production (Džuban et al., 2009b), EU regulation on organic farming (EC, 2007) and standards for biodynamic certification (Demeter International, 2009). Earthworm population and body mass were evaluated in October 2009 on plots where white cabbage, oil pumpkins and wheat were grown in crop rotation. Earthworms were collected using mustard aqueous solution, which was prepared by mixing 50 g of powdered white mustard and 100 g of water and then dissolving it in 13 L of water. The soil surface was cleared of weeds and litter, and a rectangular metal frame (50 x 50 cm) was pressed down into the soil (5 cm deep). Mustard solution was poured inside the frame, 20 minutes later the soil was dug to a depth of 10 cm and earthworms that emerged were collected. The mustard solution served as a non-toxic irritant that drove deep burrowing earthworm species to the surface (Lawrence and Bowers, 2002). Earthworms (ERW) were counted, divided into three groups (i.e. small, middle and large) and weighed. After measurements, earthworms were returned back to the soil. Differences in earthworm population and biomass among production systems and investigated crops were analysed using a two factor (system, crop) ANOVA for a randomized complete block design, followed by a Duncan test (α = 0.05). Analyses were carried out using the Statgraphic Centurion XV statistical program (Statgraphic®, 2005). Results are presented as mean of four replications ± standard error of mean (±SEM).

Results and discussion

Total earthworm population, total earthworm body mass and the populations of different earthworm groups as affected by production systems (PS) and crop species (C) are presented in Table 1. Studied production systems significantly influenced the population of small earthworms and thus the total earthworm population (Table 1). Both were demonstrated to be higher in the biodynamic and organic production systems than in control, conventional and integrated production systems. When compared to control plots, managed without fertilizers and plant protection agents, there were roughly 2.7 and 2.5 times more small earthworms in biodynamic (13.25/0.25 m²) and organic (12.30/0.25 m²) production systems, respectively. In the same manner the total earthworm population in the biodynamic production system was 207% and in the organic production system 193% of that counted in control treatments (11.58/0.25 m²). Similarly, the beneficial effect of organic farming on earthworms was emphasised by other investigations (Hansen et al., 2001; Vazquez et al., 2003; Riley et al., 2008; Irmler, 2010). The abundance of earthworms as well as their total body mass was affected by plant species occurred in crop rotation (Table 1). The oil pumpkins revealed to have a beneficial effect on earthworms.

In comparison to white cabbage and wheat, the cropping of oil pumpkins favoured the populations of middle (6.26/0.25 m²) and large (6.73/0.25 m²) earthworms, and therefore the total earthworm population (21.95/0.25 m²) and their total body mass (26.78 g/0.25 m²). Lower earthworm population and especially lower abundance of earthworms in the large earthworm population, which were observed in wheat plots, might be attributed to tillage intensity. In the period between wheat harvest and soil sampling in October, the harrowing was performed on these plots. Small earthworms were favoured by white cabbage. Results are supported by Curry et al. (2002), who found a drastic decline of earthworm abundance by intensive cultivation. The abundance of 11.25/0.25 m² was higher, but statistically the same as in plots cropped by oil pumpkins (8.90/0.25 m²).
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Table 1. The influence of production systems (PS) and plant species in crop rotation (C) on total earthworm (ERW) population, total body mass of earthworms and the populations of different earthworm groups

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Total ERW population (no./0.25 m²)</th>
<th>Total ERW body mass (g/0.25 m²)</th>
<th>Small ERW (no./0.25 m²)</th>
<th>Middle ERW (no./0.25 m²)</th>
<th>Large ERW (no./0.25 m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS</td>
<td>**</td>
<td>ns</td>
<td>**</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>C</td>
<td>**</td>
<td>ns</td>
<td>**</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>PSxC</td>
<td>ns</td>
<td>ns</td>
<td>**</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PS</th>
<th>Biodynamic</th>
<th>Control</th>
<th>Conventional</th>
<th>Organic</th>
<th>Integrated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24.00±3.63a</td>
<td>11.58±1.72b</td>
<td>11.25±1.24b</td>
<td>22.41±3.01a</td>
<td>13.00±2.35b</td>
</tr>
<tr>
<td>C</td>
<td>Cabbage</td>
<td>Oil pumpkins</td>
<td>Wheat</td>
<td>Cabbage</td>
<td>Oil pumpkins</td>
</tr>
<tr>
<td></td>
<td>15.50±2.22b</td>
<td>21.95±2.65a</td>
<td>12.05±1.26b</td>
<td>11.25±1.95a</td>
<td>10.05±1.26b</td>
</tr>
</tbody>
</table>

***, ** significant at the 0.01 and 0.05 probability levels, respectively; ns - non significant

<mean values (± SEM) followed by different letters within a column and particular factor are significantly different (Duncan, α=0.05)

There was also a significant production system and plant species interaction concerning the population of small earthworms (Table 1). Therefore, all pairwise comparisons of production systems are presented for the three plant species occurred in crop rotation (Figure 1). The beneficial effect of the organic production system was mainly attributed to the highest abundance of earthworms in plots where white cabbage was grown (23.0/0.25 m²) and the beneficial effect of biodynamic production to numerous small earthworms, identified in plots cropped by oil pumpkins (19.5/0.25 m²) and white cabbage (13.8/0.25 m²). Different production systems had no effect on the population of small earthworms, identified in plots where wheat was grown in 2009 (Figure 1).

To form a picture of how large is the mass proportion of earthworms in soil, the results obtained on sampled area were converted into values expressing the earthworm body mass per hectare (Table 2). On average, the earthworm mass achieved in soil after oil pumpkins was 1,126 kg/ha and the values derived from different production systems ranked as follows: integrated (527 kg/ha), control (560 kg/ha), conventional (606 kg/ha), biodynamic (753 kg/ha) and organic (890 kg/ha).

Figure 1. Population of small earthworms (no./0.25 m²) as influenced by production system and plant species interaction.

Mean values (± SEM) followed by different letters are significantly different (Duncan, α=0.05)
Table 2. Earthworm body mass (in kg ha\(^{-1}\)) after cropping white cabbage, oil pumpkins and wheat produced in different systems

<table>
<thead>
<tr>
<th>Production system</th>
<th>Cabbage (kg ha(^{-1}))</th>
<th>Oil pumpkins (kg ha(^{-1}))</th>
<th>Wheat (kg ha(^{-1}))</th>
<th>Average (kg ha(^{-1}))</th>
<th>Index (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biodynamic</td>
<td>240</td>
<td>1,440</td>
<td>580</td>
<td>753</td>
<td>134</td>
</tr>
<tr>
<td>Control</td>
<td>370</td>
<td>900</td>
<td>410</td>
<td>560</td>
<td>100</td>
</tr>
<tr>
<td>Conventional</td>
<td>110</td>
<td>800</td>
<td>910</td>
<td>606</td>
<td>108</td>
</tr>
<tr>
<td>Organic</td>
<td>550</td>
<td>1,380</td>
<td>740</td>
<td>890</td>
<td>159</td>
</tr>
<tr>
<td>Integrated</td>
<td>170</td>
<td>1,110</td>
<td>300</td>
<td>527</td>
<td>94</td>
</tr>
<tr>
<td>Average</td>
<td>288</td>
<td>1,126</td>
<td>588</td>
<td>667</td>
<td></td>
</tr>
<tr>
<td>Index (%)</td>
<td>49</td>
<td>191</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Conclusions**

Although production systems investigated in a long-term study are a complex set of management factors applied over a range of years, it was found that the number of earthworms and their body mass were consistently varied by different production systems and by plant species occurred in crop rotation. Differences obtained by earthworm sampling in 2009 could mainly refer to the use of livestock manure (higher abundance in organic and biodynamic treatments) and less to applied pesticides (no differences between control, conventional and integrated production systems). The oil pumpkins in crop rotation seem to have a beneficial effect on earthworms, and small earthworms were favoured by white cabbage. Lower earthworm population and especially lower abundance of large earthworms revealed on plots after wheat may be attributed to tillage intensity.

**Acknowledgement**

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**References**

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